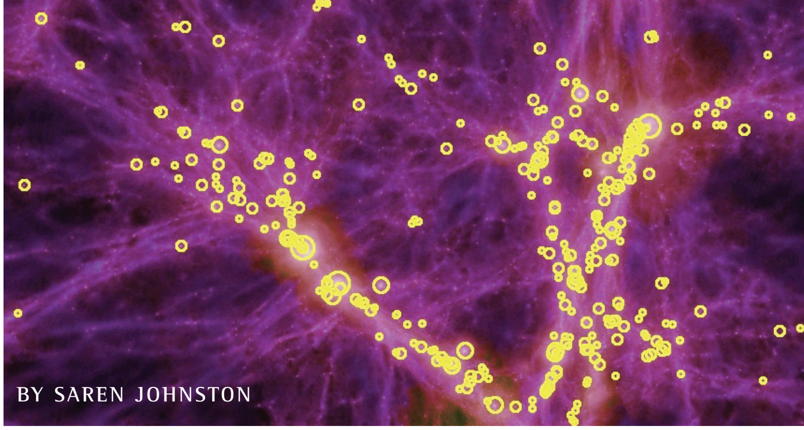
Spinning Toward Reality

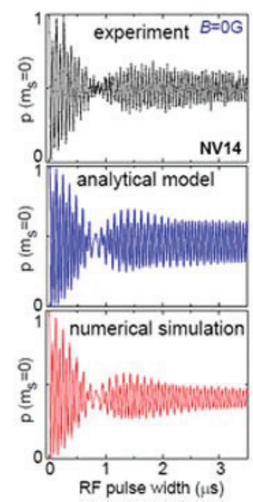


Quantum computing takes a step forward

BY SAREN JOHNSTON

RESEARCHERS AT AMES LABORATORY; The University of California, Santa Barbara; and Microsoft Station Q have teamed up to learn how quantum-mechanical states break down. The scientists made significant advancements in understanding one of the fundamental problems of quantum mechanics, which is also blocking efforts to develop practical quantum computers: the problem of decoherence. Their respective theoretical and experimental studies investigate how a single microscopic object loses its quantum-mechanical properties through interactions with the environment.

"Quantum-mechanical particles can interact with their environments: visible light, or photons; molecules of the air; crystal vibrations; and many other things," says Viatcheslav Dobrovitski, an Ames Laboratory theoretical physicist. "All these uncontrollable interactions randomly 'kick' the system, destroying quantum phases, or the ability of particles to preserve coherence between different quantum states."



These images depicting coherently driven spin oscillations of a nitrogen-vacancy (N-V) center show the excellent level of agreement achieved between experiment, analytical theory and computer simulation.

Quantum coherence is essential to developing quantum computers in which information would be stored and processed on quantum mechanical states of quantum bits, called qubits. So the self-destructive nature of quantum-mechanical states interacting with the environment is a huge problem.

To find out more about how quantum coherence breaks down and to study the dynamics of this decoherence process, the Ames Lab, UCSB and Microsoft Station Q team studied certain spin systems called nitrogen-vacancy, N-V, impurity centers in diamond. The researchers were able to manipulate a single N-V center interacting with an environment of nitrogen spins in a piece of diamond. Amazingly, they were able to tune and adjust the environmental interference extremely well, accessing surprisingly different regimes of decoherence in a single system. They showed that the degree of interaction between the qubit and the interfering environment could be regulated by applying a moderate magnetic field. By using analytical theory and advanced computer simulations, the scientists gained a clear qualitative picture of the decoherence process in different regimes, and also provided an excellent quantitative description of the quantum spin dynamics. The experiments were performed at room temperature rather than at the extremely low temperatures often required for most atomic-scale investigations.

Dobrovitski notes that quantum coherence of N-V centers in diamond is being studied by leading scientific groups worldwide. "The combined efforts of these groups could help in opening the way to developing a series of interacting qubits – steps to a quantum computer – where each N-V center would act as a qubit," he says.

"In addition to quantum computers, quantum coherence plays an important role for future less exotic, but not less spectacular, applications," says Dobrovitski. For instance, quantum spins can be employed to develop coherent spintronic devices, which would work much faster than traditional microelectronic elements and dissipate much less energy. Quantum coherence between many spins can be employed to drastically increase the sensitivity of modern nuclear magnetic resonance, NMR, or electron spin resonance, ESR, experiments," he adds. "From the application point of view, it is important to understand the loss of coherence of quantum systems in solid-state environments, which form the basis of modern technology."

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Note: This research was selected as the basis for the cover of the April 18, 2008 issue of Science *magazine -- http://www.sciencemag.org/content/vol320/issue5874/cover.dtl A professional article about the research appears on pages 352-355.*

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